In [11]:
```
import pandas as pd
from automlbench import (
    load_data, preprocess_data, get_models, get_hyperparameter_grids,
    evaluate_model, plot_performance, tune_hyperparameters,
    time_execution, log_message, suppress_warnings
)


# Load dataset
url = "https://raw.githubusercontent.com/datasciencedojo/datasets/master/titanic.cs
df = pd.read_csv(url)

# Define target column
target_column = "Survived"

# Preprocess the data
X_train, X_test, y_train, y_test = preprocess_data(df, target_column)

# Get default models
models = get_models()

# Train all models without tuning
results = train_models(X_train, X_test, y_train, y_test)

# Display results
print(results)
```

```
Random Forest: Unique Predictions - [0 1]
Gradient Boosting: Unique Predictions - [0 1]
Extra Trees: Unique Predictions - [0 1]
AdaBoost: Unique Predictions - [0 1]
Decision Tree: Unique Predictions - [0 1]
Logistic Regression: Unique Predictions - [0 1]
Support Vector Machine: Unique Predictions - [0 1]
K-Nearest Neighbors: Unique Predictions - [0 1]
Naive Bayes: Unique Predictions - [0 1]
Neural Network: Unique Predictions - [0 1]
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:04:22] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
XGBoost: Unique Predictions - [0 1]
[LightGBM] [Info] Number of positive: 439, number of negative: 439
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.000181 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 676
[LightGBM] [Info] Number of data points in the train set: 878, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.500000 -> initscore=0.000000
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
LightGBM: Unique Predictions - [0 1]
CatBoost: Unique Predictions - [0 1]
{'Random Forest': {'Accuracy': 0.8324022346368715, 'Precision': 0.8322444212984883,
'Recall': 0.8324022346368715, 'F1-Score': 0.8294988766091814, 'RMSE': 0.409387060571
20133}, 'Gradient Boosting': {'Accuracy': 0.8379888268156425, 'Precision': 0.8370669
697935873, 'Recall': 0.8379888268156425, 'F1-Score': 0.8361582536512363, 'RMSE': 0.4
025061157105039}, 'Extra Trees': {'Accuracy': 0.8379888268156425, 'Precision': 0.837
6367306699215, 'Recall': 0.8379888268156425, 'F1-Score': 0.8355208999366281, 'RMSE':
0.4025061157105039}, 'AdaBoost': {'Accuracy': 0.8268156424581006, 'Precision': 0.827
3237807244265, 'Recall': 0.8268156424581006, 'F1-Score': 0.8270432096964196, 'RMSE':
0.41615424729527806}, 'Decision Tree': {'Accuracy': 0.8100558659217877, 'Precision':
0.8100558659217877, 'Recall': 0.8100558659217877, 'F1-Score': 0.8100558659217877, 'R
MSE': 0.43582580703557733}, 'Logistic Regression': {'Accuracy': 0.8044692737430168,
'Precision': 0.8080282996484114, 'Recall': 0.8044692737430168, 'F1-Score': 0.8056140
299871624, 'RMSE': 0.4421885641408914}, 'Support Vector Machine': {'Accuracy': 0.843
5754189944135, 'Precision': 0.8429038963204727, 'Recall': 0.8435754189944135, 'F1-Sc
ore': 0.8431298534814802, 'RMSE': 0.3955054753168236}, 'K-Nearest Neighbors': {'Accu
racy': 0.6424581005586593, 'Precision': 0.7602291086757634, 'Recall': 0.642458100558
6593, 'F1-Score': 0.6345830248367773, 'RMSE': 0.5979480742015487}, 'Naive Bayes':
{'Accuracy': 0.46368715083798884, 'Precision': 0.5990266218219131, 'Recall': 0.46368
715083798884, 'F1-Score': 0.41322422430298733, 'RMSE': 0.7323338372368241}, 'Neural
Network': {'Accuracy': 0.8100558659217877, 'Precision': 0.8091833331348048, 'Recal
l': 0.8100558659217877, 'F1-Score': 0.8095148220846544, 'RMSE': 0.4358258070355773
3}, 'XGBoost': {'Accuracy': 0.8547486033519553, 'Precision': 0.8547486033519553, 'Re
call': 0.8547486033519553, 'F1-Score': 0.8547486033519553, 'RMSE': 0.381118612308615
43}, 'LightGBM': {'Accuracy': 0.8603351955307262, 'Precision': 0.8600036118931945,
'Recall': 0.8603351955307262, 'F1-Score': 0.8601414536874885, 'RMSE': 0.373717546375
96794}, 'CatBoost': {'Accuracy': 0.8324022346368715, 'Precision': 0.831218867820678
8, 'Recall': 0.8324022346368715, 'F1-Score': 0.8308179436127229, 'RMSE': 0.409387060
57120133}}
```

In [12]:
```python
# Evaluate models
for model_name, model in models.items():
    print(f"Evaluating {model_name}...")
    metrics = evaluate_model(model.fit(X_train, y_train), X_test, y_test)
```

```
Evaluating Random Forest...
Evaluating Gradient Boosting...
Evaluating Extra Trees...
Evaluating AdaBoost...
Evaluating Decision Tree...
Evaluating Logistic Regression...
Evaluating Support Vector Machine...
Evaluating K-Nearest Neighbors...
Evaluating Naive Bayes...
Evaluating Neural Network...
Evaluating XGBoost...
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:04:52] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
Evaluating LightGBM...
[LightGBM] [Info] Number of positive: 273, number of negative: 439
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000096 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 444
[LightGBM] [Info] Number of data points in the train set: 712, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383427 -> initscore=-0.475028
[LightGBM] [Info] Start training from score -0.475028
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
Evaluating CatBoost...
```
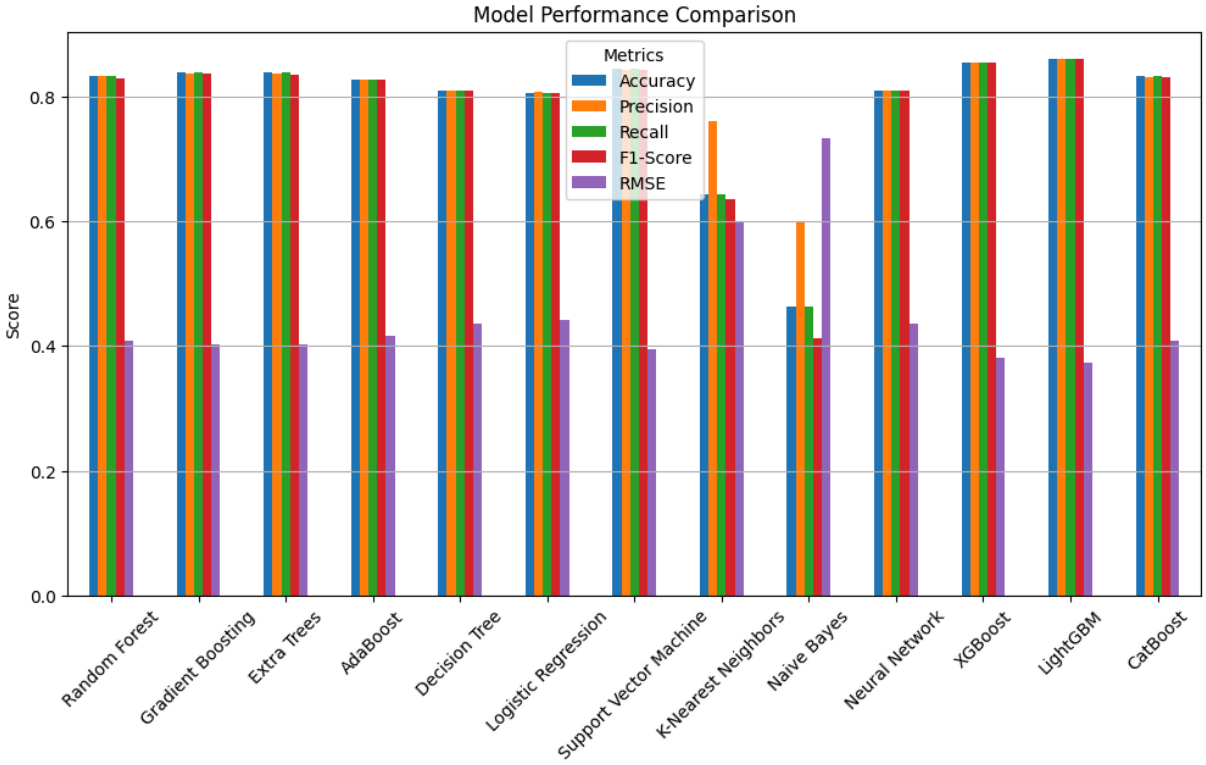

In [14]:

```python
# Plot performance comparison
plot_performance(results, metrics=["Accuracy", "Precision", "Recall", "F1-Score", "
```



In [17]:
```
# Hyperpara,eter tuning
hyperparameter_grids = get_hyperparameter_grids()
# Load predefined hyperparameter grid
rf_param_grid = hyperparameter_grids["Random Forest"]

# Tune hyperparameters
best_rf_model, best_rf_params = tune_hyperparameters(models["Random Forest"], rf_pa

print(f"Best Random Forest Model: {best_rf_model}")
print(f"Best Parameters: {best_rf_params}")
```

```
Best Random Forest Model: RandomForestClassifier(max_depth=20, n_estimators=200)
Best Parameters: {'max_depth': 20, 'n_estimators': 200}
```

In [18]:
```
#Apply Hyperparameter Tuning to Multiple Models

best_models = {}

for model_name, model in models.items():
    if model_name in hyperparameter_grids:  # Ensure a grid exists for this model
        print(f"Tuning {model_name}...")
        best_model, best_params = tune_hyperparameters(model, hyperparameter_grids[
        best_models[model_name] = best_model
        print(f"Best params for {model_name}: {best_params}")
    else:
        best_models[model_name] = model  # Use default model if no grid is availabl
```

```
Tuning Random Forest...
Best params for Random Forest: {'max_depth': 20, 'n_estimators': 100}
Tuning Gradient Boosting...
Best params for Gradient Boosting: {'learning_rate': 0.2, 'n_estimators': 200}
Tuning Extra Trees...
Best params for Extra Trees: {'max_depth': None, 'n_estimators': 100}
Tuning AdaBoost...
Best params for AdaBoost: {'learning_rate': 0.01, 'n_estimators': 50}
Tuning Decision Tree...
Best params for Decision Tree: {'max_depth': None, 'min_samples_split': 10}
Tuning Logistic Regression...
Best params for Logistic Regression: {'C': 10}
Tuning Support Vector Machine...
Best params for Support Vector Machine: {'C': 10, 'kernel': 'linear'}
Tuning K-Nearest Neighbors...
Best params for K-Nearest Neighbors: {'n_neighbors': 10}
Tuning Neural Network...
Best params for Neural Network: {'alpha': 0.01, 'hidden_layer_sizes': (50,)}
Tuning XGBoost...
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:29] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
Best params for XGBoost: {'learning_rate': 0.01, 'n_estimators': 100}
Tuning LightGBM...
[LightGBM] [Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.419418 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 374
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.107622 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.112742 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
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[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000067 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.000105 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 374
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
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[LightGBM] [Info] Number of positive: 218, number of negative: 351
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You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
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[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
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[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
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[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.071936 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000068 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.066570 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
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[Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.220349 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
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[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
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[LightGBM] [Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
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You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf[LightGBM]
[Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.330848 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.026942 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
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[LightGBM] [Info] Number of positive: 218, number of negative: 352
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[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000070 seconds.
You can set `force_row_wise=true` to remove the overhead.
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[LightGBM] [Info] Total Bins 373
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[LightGBM] [Info] Start training from score -0.479136
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000070 seconds.
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You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.019717 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.057157 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000071 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
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[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
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You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
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[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000068 seconds.
```

```
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.065125 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 380
```

```
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.012223 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
```

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[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.001050 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
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And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 374
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf[LightGBM]
[Info] Number of positive: 218, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.243776 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 569, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383128 -> initscore=-0.476291
[LightGBM] [Info] Start training from score -0.476291
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000068 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
```

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[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.070983 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
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[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.051697 seconds.
You can set `force_row_wise=true` to remove the overhead.
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[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[Info] Number of positive: 218, number of negative: 351
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf[LightGBM]
```

```
[Info] Number of positive: 273, number of negative: 439
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000106 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 444
[LightGBM] [Info] Number of data points in the train set: 712, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383427 -> initscore=-0.475028
[LightGBM] [Info] Start training from score -0.475028
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
Best params for LightGBM: {'learning_rate': 0.01, 'n_estimators': 50}
Tuning CatBoost...
Best params for CatBoost: {'iterations': 100, 'learning_rate': 0.2}
```

In [19]:
```python
# Train and Evaluate Tuned Models

# Train tuned models
results = train_models(X_train, X_test, y_train, y_test, selected_models=list(best_

# Display evaluation results
for model_name, model in best_models.items():
    print(f"Evaluating {model_name}...")
    metrics = evaluate_model(model.fit(X_train, y_train), X_test, y_test)
    print(metrics)

# Plot performance comparison
plot_performance(results, metrics=["Accuracy", "Precision", "Recall", "F1-Score", "
```

```
Random Forest: Unique Predictions - [0 1]
Gradient Boosting: Unique Predictions - [0 1]
Extra Trees: Unique Predictions - [0 1]
AdaBoost: Unique Predictions - [0 1]
Decision Tree: Unique Predictions - [0 1]
Logistic Regression: Unique Predictions - [0 1]
Support Vector Machine: Unique Predictions - [0 1]
K-Nearest Neighbors: Unique Predictions - [0 1]
Naive Bayes: Unique Predictions - [0 1]
Neural Network: Unique Predictions - [0 1]
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:13:29] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
XGBoost: Unique Predictions - [0 1]
[LightGBM] [Info] Number of positive: 439, number of negative: 439
[LightGBM] [Info] Auto-choosing col-wise multi-threading, the overhead of testing wa
s 0.000170 seconds.
You can set `force_col_wise=true` to remove the overhead.
[LightGBM] [Info] Total Bins 676
[LightGBM] [Info] Number of data points in the train set: 878, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.500000 -> initscore=0.000000
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
LightGBM: Unique Predictions - [0 1]
CatBoost: Unique Predictions - [0 1]
Evaluating Random Forest...
{'Accuracy': 0.8212290502793296, 'Precision': 0.8270672444955636, 'Recall': 0.821229
0502793296, 'F1 Score': 0.81458147504812, 'AUC-ROC': 0.8955204216073781}
Evaluating Gradient Boosting...
{'Accuracy': 0.8379888268156425, 'Precision': 0.8376367306699215, 'Recall': 0.837988
8268156425, 'F1 Score': 0.8355208999366281, 'AUC-ROC': 0.905270092226614}
Evaluating Extra Trees...
{'Accuracy': 0.8268156424581006, 'Precision': 0.8260480728604291, 'Recall': 0.826815
6424581006, 'F1 Score': 0.8241775137253613, 'AUC-ROC': 0.8937417654808959}
Evaluating AdaBoost...
{'Accuracy': 0.7877094972067039, 'Precision': 0.785981498654242, 'Recall': 0.7877094
972067039, 'F1 Score': 0.786436433157437, 'AUC-ROC': 0.7705533596837945}
Evaluating Decision Tree...
{'Accuracy': 0.8324022346368715, 'Precision': 0.831539176773188, 'Recall': 0.8324022
346368715, 'F1 Score': 0.8301856919910434, 'AUC-ROC': 0.8478919631093543}
Evaluating Logistic Regression...
{'Accuracy': 0.8156424581005587, 'Precision': 0.8151835700307604, 'Recall': 0.815642
4581005587, 'F1 Score': 0.8153867188674848, 'AUC-ROC': 0.8988142292490118}
Evaluating Support Vector Machine...
{'Accuracy': 0.8324022346368715, 'Precision': 0.8316637085919167, 'Recall': 0.832402
2346368715, 'F1 Score': 0.8319248430158716, 'AUC-ROC': 0.8988142292490119}
Evaluating K-Nearest Neighbors...
{'Accuracy': 0.8212290502793296, 'Precision': 0.8215568227281274, 'Recall': 0.821229
0502793296, 'F1 Score': 0.8173395345423856, 'AUC-ROC': 0.8800395256916995}
Evaluating Naive Bayes...
{'Accuracy': 0.46368715083798884, 'Precision': 0.5990266218219131, 'Recall': 0.46368
715083798884, 'F1 Score': 0.41322422430298733, 'AUC-ROC': 0.5393280632411067}
Evaluating Neural Network...
{'Accuracy': 0.8324022346368715, 'Precision': 0.8324022346368715, 'Recall': 0.832402
2346368715, 'F1 Score': 0.8324022346368715, 'AUC-ROC': 0.8906455862977601}
Evaluating XGBoost...
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:13:42] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
{'Accuracy': 0.7988826815642458, 'Precision': 0.8023486279986854, 'Recall': 0.798882
6815642458, 'F1 Score': 0.7914041594291348, 'AUC-ROC': 0.9020421607378131}
Evaluating LightGBM...
[LightGBM] [Info] Number of positive: 273, number of negative: 439
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.000116 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 444
[LightGBM] [Info] Number of data points in the train set: 712, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.383427 -> initscore=-0.475028
[LightGBM] [Info] Start training from score -0.475028
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```

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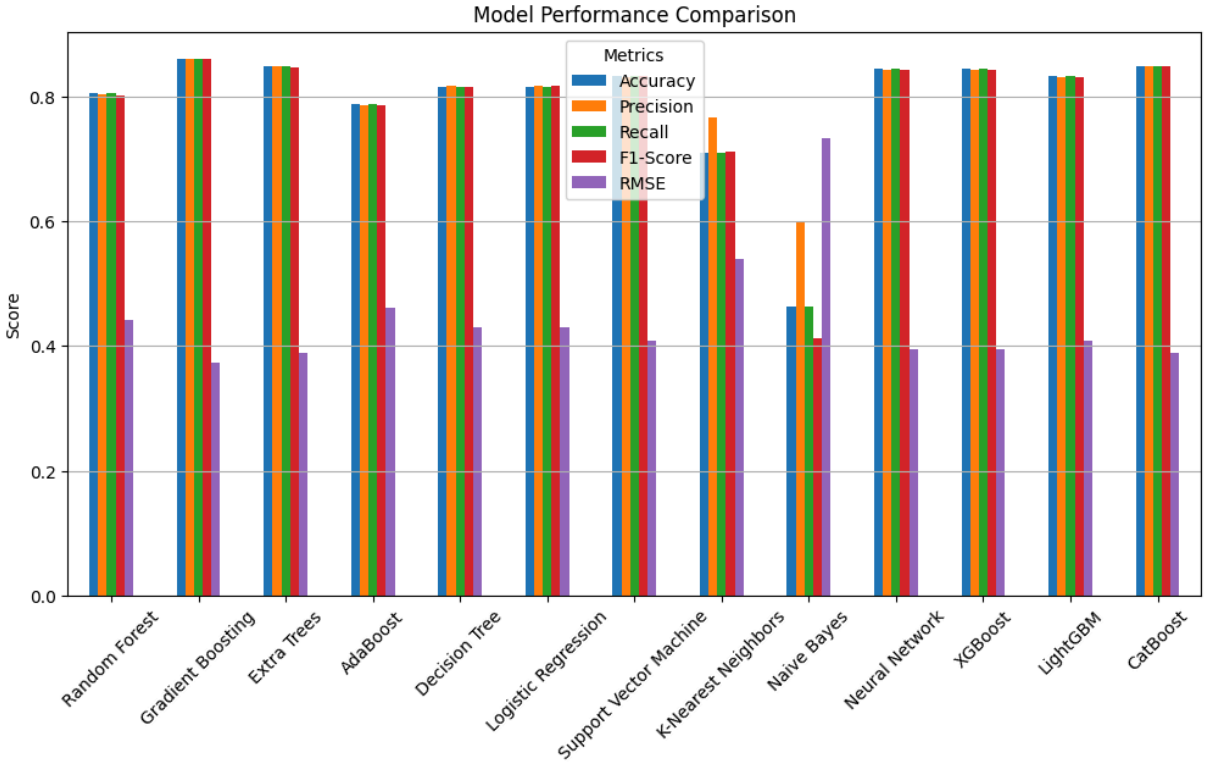
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
{'Accuracy': 0.7877094972067039, 'Precision': 0.8060392068579417, 'Recall': 0.787709
4972067039, 'F1 Score': 0.772674847228821, 'AUC-ROC': 0.8965085638998683}
Evaluating CatBoost...
{'Accuracy': 0.8770949720670391, 'Precision': 0.8788624814569328, 'Recall': 0.877094
9720670391, 'F1 Score': 0.8749658428467332, 'AUC-ROC': 0.9183794466403162}
```



```
[LightGBM] [Info] Number of positive: 219, number of negative: 351
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.622802 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 380
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 379
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.384211 -> initscore=-0.471714
[LightGBM] [Info] Start training from score -0.471714
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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```
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:25] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:26] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:27] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:28] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:28] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
```

```
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:25] WARNING: /workspace/src/learner.cc:740: 
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:26] WARNING: /workspace/src/learner.cc:740: 
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
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/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:28] WARNING: /workspace/src/learner.cc:740:
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/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
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Parameters: { "use_label_encoder" } are not used.

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/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
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Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

```
[LightGBM] [Info] Number of positive: 218, number of negative: 352
[LightGBM] [Info] Auto-choosing row-wise multi-threading, the overhead of testing wa
s 0.532825 seconds.
You can set `force_row_wise=true` to remove the overhead.
And if memory is not enough, you can set `force_col_wise=true`.
[LightGBM] [Info] Total Bins 373
[LightGBM] [Info] Number of data points in the train set: 570, number of used featur
es: 12
[LightGBM] [Info] [binary:BoostFromScore]: pavg=0.382456 -> initscore=-0.479136
[LightGBM] [Info] Start training from score -0.479136
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
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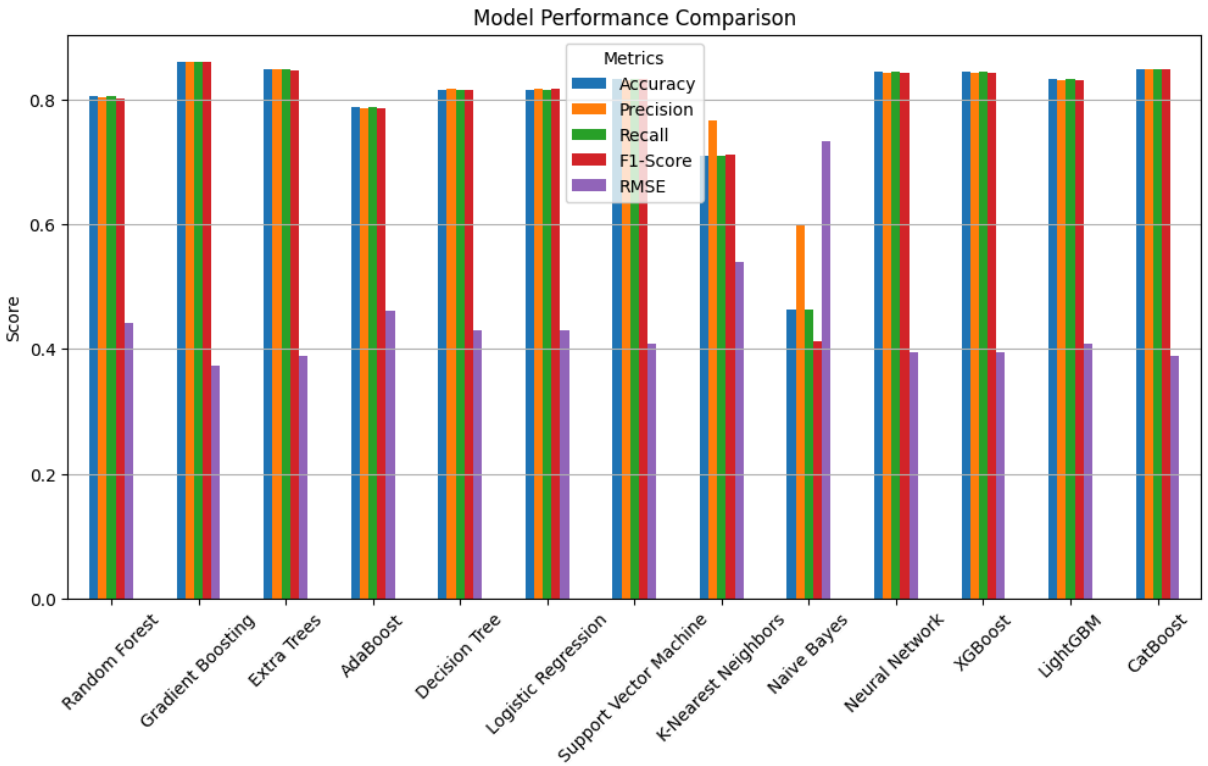
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
[LightGBM] [Warning] No further splits with positive gain, best gain: -inf
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:26] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:27] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/xgboost/cor
e.py:158: UserWarning: [13:11:27] WARNING: /workspace/src/learner.cc:740:
Parameters: { "use_label_encoder" } are not used.

  warnings.warn(smsg, UserWarning)
```

In [20]:
```
# Plot performance comparison
plot_performance(results, metrics=["Accuracy", "Precision", "Recall", "F1-Score", "
```



In [22]:
```
!jupyter nbconvert --to webpdf --output test.pdf Test.ipynb
```

```
[NbConvertApp] Converting notebook Test.ipynb to webpdf
[NbConvertApp] WARNING | Alternative text is missing on 3 image(s).
[NbConvertApp] Building PDF
Traceback (most recent call last):
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/webpdf.py", line 78, in main
    from playwright.async_api import async_playwright  # type: ignore[import-not-fou
nd]
ModuleNotFoundError: No module named 'playwright'

The above exception was the direct cause of the following exception:

Traceback (most recent call last):
  File "/home/magus/.pyenv/versions/magus/bin/jupyter-nbconvert", line 8, in <module
>
    sys.exit(main())
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/jup
yter_core/application.py", line 283, in launch_instance
    super().launch_instance(argv=argv, **kwargs)
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/tra
itlets/config/application.py", line 1075, in launch_instance
    app.start()
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/nbconvertapp.py", line 420, in start
    self.convert_notebooks()
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/nbconvertapp.py", line 597, in convert_notebooks
    self.convert_single_notebook(notebook_filename)
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/nbconvertapp.py", line 563, in convert_single_notebook
    output, resources = self.export_single_notebook(
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/nbconvertapp.py", line 487, in export_single_notebook
    output, resources = self.exporter.from_filename(
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/templateexporter.py", line 386, in from_filename
    return super().from_filename(filename, resources, **kw)  # type:ignore[return-va
lue]
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/exporter.py", line 201, in from_filename
    return self.from_file(f, resources=resources, **kw)
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/templateexporter.py", line 392, in from_file
    return super().from_file(file_stream, resources, **kw)  # type:ignore[return-val
ue]
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/exporter.py", line 220, in from_file
    return self.from_notebook_node(
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/webpdf.py", line 174, in from_notebook_node
    pdf_data = self.run_playwright(html)
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/webpdf.py", line 163, in run_playwright
    pdf_data = pool.submit(run_coroutine, main(temp_file)).result()
  File "/home/magus/.pyenv/versions/3.8.7/lib/python3.8/concurrent/futures/_base.p
y", line 439, in result
```

```
    return self.__get_result()
  File "/home/magus/.pyenv/versions/3.8.7/lib/python3.8/concurrent/futures/_base.p
y", line 388, in __get_result
    raise self._exception
  File "/home/magus/.pyenv/versions/3.8.7/lib/python3.8/concurrent/futures/thread.p
y", line 57, in run
    result = self.fn(*self.args, **self.kwargs)
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/webpdf.py", line 161, in run_coroutine
    return loop.run_until_complete(coro)
  File "/home/magus/.pyenv/versions/3.8.7/lib/python3.8/asyncio/base_events.py", lin
e 616, in run_until_complete
    return future.result()
  File "/home/magus/.pyenv/versions/3.8.7/envs/magus/lib/python3.8/site-packages/nbc
onvert/exporters/webpdf.py", line 84, in main
    raise RuntimeError(msg) from e
RuntimeError: Playwright is not installed to support Web PDF conversion. Please inst
all `nbconvert[webpdf]` to enable.
```

In [ ]: